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This report contains information on national-level science policies, technology strategies, and research and development programs in West European science and technology in general and specifically in civil technology, with particular attention to transportation, energy, chemical manufacturing, industrial automation and technology transfer. The report will focus primarily on France and the Federal Republic of Germany, but will also cover important developments in Italy, the Netherlands, Sweden and other West European countries.

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No. 13

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FEDERAL REPUBLIC OF GERMANY

ADVANTAGES, PRACTICAL USES OF WATER-INSULATED CABLE

Graefelfing ENERGIE in German No 10, Oct 79 pp 334-337

[Unattributed article]

[Text] 200 MVA transmission power at 110 kV, 600 MVA at 400 kV, these are about limit values for calculations with conventional cables. 2000 and 5000 MVA are supposed to be the new limit values achieved by a cable internally cooled by water. A test line is being built in Berlin, for testing the values and economy of the new cable competition.

One side is normal with the competition, while the other represents the actual contractor - the collaboration of the partners should yield an economical high power cable. In 1982, the electrical utilities will know what to think of a cable whose development was begun in 1974.

The cable manufacturers and competitors Felten and Guilleaume Carlswerk AG in Cologne and the Cable and Enamel Wire Factory GmbH, Mannheim, have entered a short term liaison: they would like water and electricity to get along, to help one another.

Once before, the two enterprises collaborated. In the beginning of the 70's, a study was made how bothersome line losses could be avoided by using nitrogen at -200° C. The resulting common denominator was that a new beginning should be made with a "water cable", in order to achieve the same effect. Cable & Wire as well as F and G are now bold enough to prophecy that their joint cable represents "a technically and economically optimum solution" in the power range up to 2000 MVA at 110 kV.

The occasion for this statement was the successful laboratory experiments, in a 300 meter long electric line of the Berlin BEWAG (Berlin Electrical Works).

The high-density population area of Berlin surely is a good example that new ideas are necessary for cables. The high voltage poles are fully loaded; more current has to flow through high power cables with only a single cable.

The limits for cables are set by the cooling system, the insulating system, and the expected reliability.

The 'Water Cable' Consists of Conventional Technology

As if it were obvious, Dr. Eng. Horst Küch, leader of special cable development of Felten and Guilleaume Carlswerk AG, Cologne, lists the arguments for the water cable that is supposed to fulfill all requirements:

The simplest and also most effective coolant is water; the loss heat can be directly dissipated where it is generated. Heat-sensitive insulation is not necessary; to make the cooling system resistant against corrosion and erosion, special steel was chosen as the material for the cooling channel.

The electrical insulation must guarantee electrical safety and must also withstand fluctuating thermal loads: paper insulation saturated with low-viscosity oil fulfills this task.

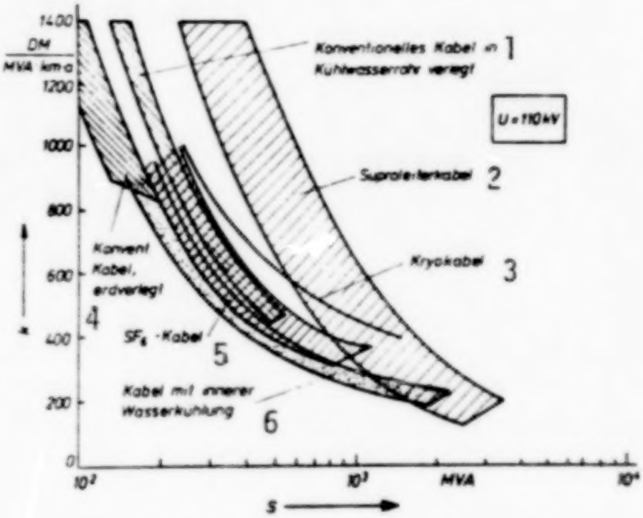
Considerations and trial assemblies at the experimental institute gave promise that a cable defect could be eliminated in about three weeks. Compared to the two weeks necessary for conventional cables, this is a tolerable time.

In all, said Küch, "conventional, proven technology was combined to make a new product." One advantage of the cable surely is that it can be wound on drums in lengths of 300 to 500 meters and can be laid in the usual ditches. The cable alone, however, does not transmit current. Küch points to the terminal connections and joints. The electric field at the cable terminal connections can be controlled in conventional winding technology. However, the high voltage in the cooling water must be dissipated by an additional "water terminal connection". The coolant here flows through a porcelain insulator, which reduces the potential. The technique for the SF_6-insulated compact terminal connection does not look much different: for the overhead terminal connection, a parallel arrangement is provided, and for the compact terminal connection a series arrangement.

SF_6, Superconductor, and Cryocable Out of the Running?

Both enterprises jointly developed the cable, the joints, and the cooling system. The cable will be marketed solely by Felten and Guilleaume. As regards joints and terminal connections, the potential customer can turn to both enterprises. Kabel + Draht (Cable and Wire) will be solely responsible for the cooling equipment. Dipl. Eng. Peter Sieper, of the K and

D (Cable and Wire) marketing department for high voltage cable systems, stated that he regards the economic considerations as the basis of this technology. If water and current actually flow as Sieper imagines, competing systems such as SF_6, superconductors, or cryocables are out of the running (see figure).



In the range of about 200 MVA to about 2000 MVA, Kabel + Draht regards a 110 kV cable with exterior water cooling as the most economical and technically most favorable solution.

1 conventional cable laid in cooling water
2 superconducting cable
3 cryocable
4 conventional cable laid in the ground
5 SF_6 cable
6 cable with internal water cooling

Five important parameters are named by Sieper for the new development:

Length of the cable layout

Distance between cooling stations

Flow speed of the cooling medium

Pressure and temperature difference between the entrance and exit of the cooling medium

Geometry and hydraulic switching of the coolant pipes

A layout length of 3 km can be an example for the project. The cooling water pipe here has an inner diameter of 60 mm with a conductor cross-section of 3500 mm^2 aluminum; the pressure difference between the water entrance and exit is 50 bar, with a water entry temperature of 30° C and an exit temperature of 80° C; the flow velocity here is 3.2 m/s, and the transmission power 1500 MVA at 110 kV.

These data are also reference points for the limit of the transmission capability of such cables: about 2000 MVA at 110 kV and about 5000 MVA at 400 kV. The strength of the cooling water pipe is indicated by the above values; to this must be added that the conductivity of the cooling water may be at most 10 μ S/cm, because of the potential drop at the terminal connection. As far as the lifetime of the system is concerned, the material should corrode as little as possible, the flange connections should have no edges against the flow, and the cooling water should be constantly deionized in a bypass.

The closed cooling circulation is possible in several variants:

Pumps and cooling equipment are located at the beginning, middle, and/or ends of the layout

The water is recycled in separate recycling pipes or in one of the cable phases.

The experimental arrangement in Berlin is designed so that two basic types of cooling can be tested:

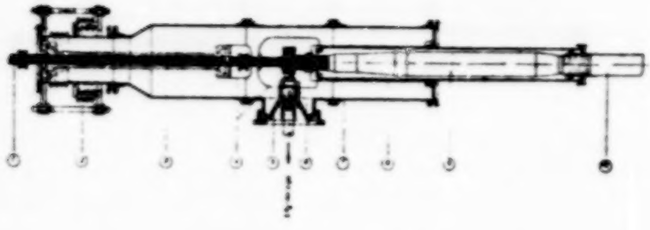
The cooling water flows to the three cable strands and returns through three return pipes

The cooling water flows through two cable strands and returns through the third cable strand.

4400 MVA at 110 kV Would Be Possible

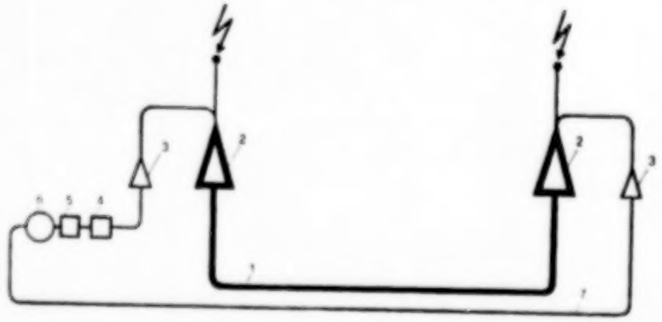
The return pipes consist of the same material and also have the same dimensions as the pipes in the cable line. If the cables tested in Berlin were to use all the maximum values, it would be possible to transmit about 4400 MVA corresponding to 23,000 A at 110 kV. The standard experimental operation is performed at various hydraulic circuits with load cycles of 5000 A.

The temperature level is controlled through the secondary circulation; an open cooling tower is provided for cooling.



The single conductor SF_6 terminal connections are the "problem element" of the cable

1 coolant pipe
2 pressure relief expansion bellows
3 water terminal connection
4 shielding electrode
5 ballast insulator
6 contact piece
7 cover body
8 cable terminal connection
9 controlled stress core
10 water cable



The basic circuit diagram of the water cable system in Berlin

1 cable with interior water cooling
2 cable terminal connection
3 water terminal connection
4 cooler
5 deionizer
6 pump
7 cooling water return

With a transmission power of 1000 MVA, a system kilometer cable will cost about one million DM. About the same sum must be calculated for the ditch. For the requirements in Berlin, it must be expected that 20 to 30 kilometers of cable will already be necessary for high power transmission by the middle of the 80s. No wonder that the engineers of the BEWAG are looking very closely at this 14 million dollar experiment (nearly half is contributed by the BMFT (Federal Ministry for Research and Technology)). Dipl. Eng. Manfred Henschel, of BEWAG Technical Planning expects important results from this major experiment, which extends over several years:

Can a heavy cable system be laid in constricted and occupied lines in a metropolitan area; questions of transport, assembly (smallest bending radius of the cable is 3.6 m), erection of cooling stations, etc.

How will the transmission capability depend on the pressure and temperature of the cooling medium, what is the effect of temperature on and from other conducting systems in the line

How reliable are the cables and fittings over several years (even under trouble simulation)?

The "water cable" has already passed one test: it was transported by boat and truck and was laid in an area which is certainly typical for Berlin circumstances.

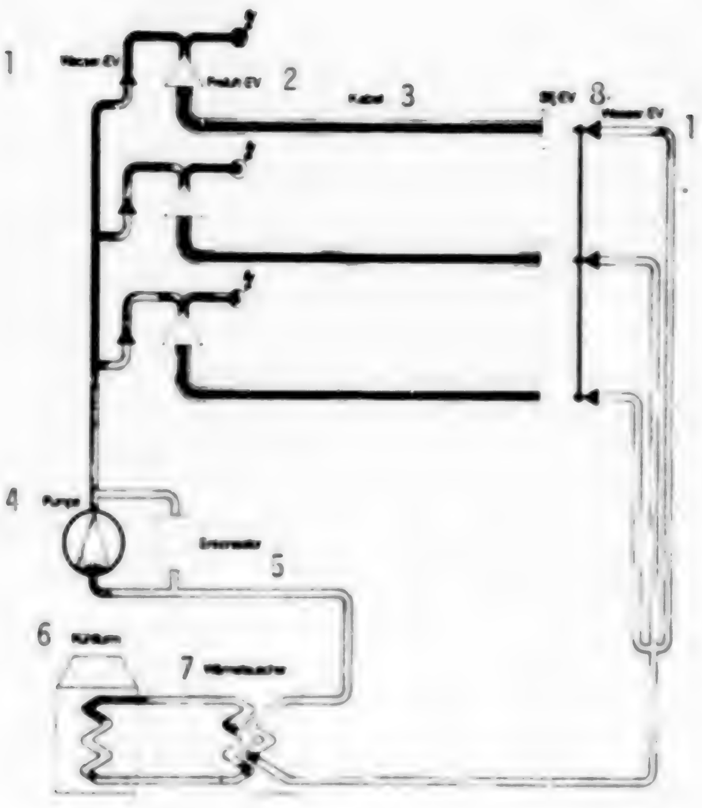
Henschel obviously sees the main problems not so much in the cable itself as in the terminal connections, "which cause headaches". On the one hand, there are overhead terminal connections for cable and cooling water for the nominal voltage of 110 kV; and more important, the fully encapsulated SF_6 terminal connections for cable and cooling water, which are already designed for the nominal voltage of 380 kV, in order to gain experience. The BEWAG, just like the cable manufacturers, seems convinced that the 380 kV cable will not pose many difficulties.

Experimental Setup

In order to simulate the anticipated transmission power of 950 MVA at 110 kV, a synthetic circuit is necessary, in which the cable will be stressed no less than under practical circumstances, but only the loss power is necessary.

The cable is short-circuited at its ends. It is fed with three-phase current through a high current transformer. It is charged with single-phase voltage through a separate supply.

With a conductor current of 5 kA, the conductor ground voltage is 63.5 kV or respectively 127 kV, in order to include the effect of a single-pole ground connection. The stresses from heat expansion are caused by a daily switch-on time of about ten hours and a subsequent cooling phase.

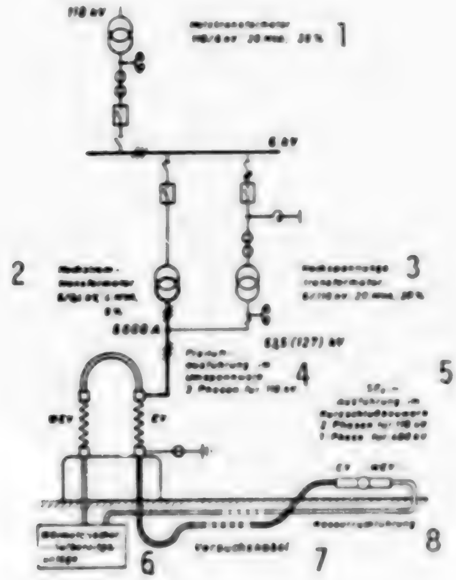


The cooling principle of the water cable system is also implemented in the Roedernallee just as it will one day work in practice

1 water terminal connection
2 open air terminal connection
3 cable
4 pump
5 deionizer
6 cooling tower
7 heat exchanger
8 SF_6 terminal connection

A 110/6 kV transformer station is being built for the experiment on the test area in the Berlin Roedernallee. Later on, this will also be used for the Berlin electrical supply. The open air fittings with the three-

phase high current and single-phase high voltage connection will be located in the interior of this building. The short circuit works with the SF_6 fittings will be situated at the other end of the area.



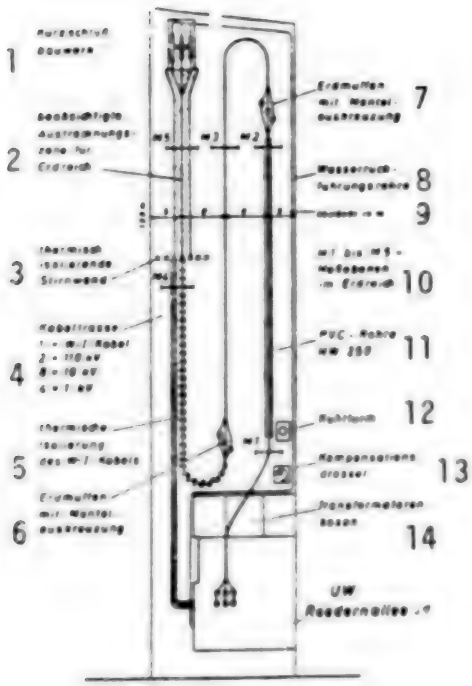
Lest all theory be gray, the test system at the Roedernallee is built thus....

1 line transformer 110/6 kV, 20 MVA, 20 percent
2 high current transformer 6/0.4 kV, 4 MVA, 9 percent
3 high voltage transformer 6/110 kV, 20 MVA, 20 percent
4 overhead design in the transformer station, three phases for 110 kV
5 SF_6 design in the short circuit works, two phases for 110 kV, one phase for 400 kV
6 heat exchanger and processing system
7 experimental cable
8 water return

The cable with three strands, each 300 meters long, will be laid in an S-shape, so that two 180 degree arcs will be pulled. The strands run through pipes along a length of about 40 m.

When the cables in a line are laid in parallel with others, and when the conductor-cooled cable is fully loaded, double insulation becomes necessary. Thermal conditions will be observed along a length of 50 m. The other cables in this piece of line will be heated with a low voltage.

....so that the experimental results will actually provide information whether the cable is suitable for practical application



1 short circuit works
2 anticipated drying zone for the ground area
3 thermal insulating front wall
4 cable layout
  1 x W-I cable
  2 x 110 kV
  8 x 10 kV
  4 x 1 kV
5 thermal insulation of the W-I cable
6 ground joints with sheath cross-jointing
7 ground joints with sheath cross-jointing
8 water return pipes

9 distances in m
10 M 1 through M 5 measurement levels in the ground area
11 PVC pipes NW 250
12 cooling tower
13 compensation choke
14 transformer boxes

The water circulation is designed so that, with a pipe length of 780 m (300 m cable, 480 m water return pipe per strand) and an initial pressure of 50 bar, the permissible flow speed of 6 m/s will be reached. The desired temperature play with this intense cooling will be reached by a cooling tower control. The temperatures at the beginning and end of the cable will differ only by about 3° K. In order to simulate the temperature difference of about 50° K, which occurs in practical operation, a second pump was installed for an intake pressure of 3 bar with a flow speed of about 0.4 m/s.

The cable sheaths are electrically cross-joined among one another in three partial lengths. The cross-joint points are grounded through voltage-dependent resistors. In order to reach the required symmetry for the electric supply in the triangle, a center distance of 30 cm was chosen.

In the section of the cable ditch where the cables are laid in pipes, the expansion conditions were made visible by x-ray pictures at the connecting joints.

Load Densities Up to 500 MW/km^2

In essence, the study involves five points of central interest which are equally interesting for all participants:

mechanical problems

hydrodynamic problems

thermal problems

electrical problems

acoustic problems

An extensive measurement system has been provided, so as to leave no question open. The data are acquired through measurement sensors as well as through data converters and a process computer. The computer simultaneously exercises the required control functions as well as data compression. Through a remote data transmission system, the data are stored at the BEWAG computer system and are there evaluated.

During the next four or five years, the cable will be spared nothing: it will be run without cooling, its conductivity will be changed, the cooling tower will be run this way and that, etc. One waits with high anticipation whether the cable will hold, and what the manufacturer, user, and BMFT can expect from it. For example, low densities of 100 to 500 MW/km^2; for example, a loss power of only 1 0/00. The BEWAG has also given some thought to using the loss energy in a sensible way. The heated cooling water could be the energy base for heat pumps. Music of the future.

"A conventional cable at 110,000 V can transmit a maximum power of 200 MVA; the cable presented here transmits five times as much, namely 1000 MVA. This means that, in place of the previous 15 cables necessary for 1000 MVA, only three cables need to be laid, and also only about one fifth as much space is required. This is based on a cooling station interval of 4 km, as is easily realizable in high density areas. The 1000 MVA value is not a limit, power increases are possible without major effort." These are Kuecht's words, which must resound the ears of cable competitors. If the test results should support this statement, the cable market has a new competitive system.

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DEVELOPMENT, MANUFACTURE OF GAS-INSULATED CABLE

Graefelfing ENERGIE in German No 10, Oct 79 pp 328-333

[Article by Dr Eng Eckhard Abilgaard, Frankfurt]

[Text] Cable engineers in principle have two possibilities for improving the transmission capability of cables. On the one hand, internal line losses can be reduced; on the other hand, heat can be dissipated further. The new flexible, SF_6-insulated tubular gas cables consist of cable metal and have an internal gas pressure. These cables kill two birds with one stone: The SF_6 gas reduces electrical losses and also promotes heat dissipation. Transmission powers in the GVA region become possible. (The editors)

The transmission power of cables is limited by the allowed heating, which in its turn is characterized by internal and external parameters [1, 2]. The internal parameters concern losses in the conductor, in the cable sheath, and in the dielectric. They depend on current and voltage. With alternating current, line losses are determined by the DC resistance, the increase of resistance caused by current displacement in the conductor (skin effect) and the influence of the neighboring conductors (proximity effect). Losses due to the skin effect can be reduced by segmenting the conductor. Here the component conductors are insulated with respect to one another. The proximity effect, on the other hand, can be reduced by larger gaps between neighboring conductors.

The conductor currents in the cable sheaths cause longitudinal voltages with single conductor cables. If the cable sheath is grounded on both sides, these voltages cause sheath currents and consequently losses. The "shielding losses" can be reduced by insulating the metal sheath against ground and by grounding the cable sheath at only one side. However, this method is suitable only for system lengths of a few hundred meters. since

otherwise the longitudinal sheath voltages would lie above the danger limit of 65 V. For larger system lengths, the cable sheaths are cross jointed.

Smaller Dielectric Constants - Smaller Losses

The losses in the insulation depend on the voltage and on the character of the dielectric.

$$P_v = U^2 \cdot \omega \cdot \frac{2\pi \varepsilon_0 \varepsilon_r}{\ln \frac{D}{d}} \cdot \tan\delta \qquad (1)$$

(D: internal diameter of the sheath, d: external diameter of the conductor).

Dielectric losses can be reduced by insulating materials with a smaller loss factor $\tan\delta$ and a small dielectric constant ε_r. For example, according to the IEC recommendations 287, a $\tan\delta = 0.0045$ is allowed for a high voltage power cable. However, most types of cables fall far below this value.

In Figure 1 are plotted the total losses, which are based on the internal parameters of the cable, in their relative proportions, as a function of conductor cross-section, for a 380 kV oil cable.

'Heat Death' in Dry Ground

The thermal conductivity and the permissible temperature of the medium surrounding the cable are the external parameters. The familiar cable types are generally laid in the ground. When the surrounding bedding material becomes warmer, the vapor pressure rises in the vicinity of the cable. The water particles dissolved in the ground flow away from the cable as steam and condense in cooler zones. This increases the capillary potential in the vicinity of the cable, so that water migrates back to the cable. If the surface temperature of the cables rises above 30° C in sandy soils and above 50° C in clayey soils, this circulation is interrupted, and the material in the vicinity of the cable dries out. As a consequence, the thermal ground resistance rises from 0.9 K·m/W to 2.5 K·m/W, and the conductor and sheath temperatures of the cables rise correspondingly. Once the ground is dried out, regeneration of the ground is no longer possible, even if the cable is completely unburdened, and the cable's "heat death" is the result. A stabilized refill mixture has recently been developed, which retains its good heat-conducting properties independent of moisture content, that is even when it dries out. The allowed surface temperature of the cable is then 90° C, and the load of the cable can therefore be increased.

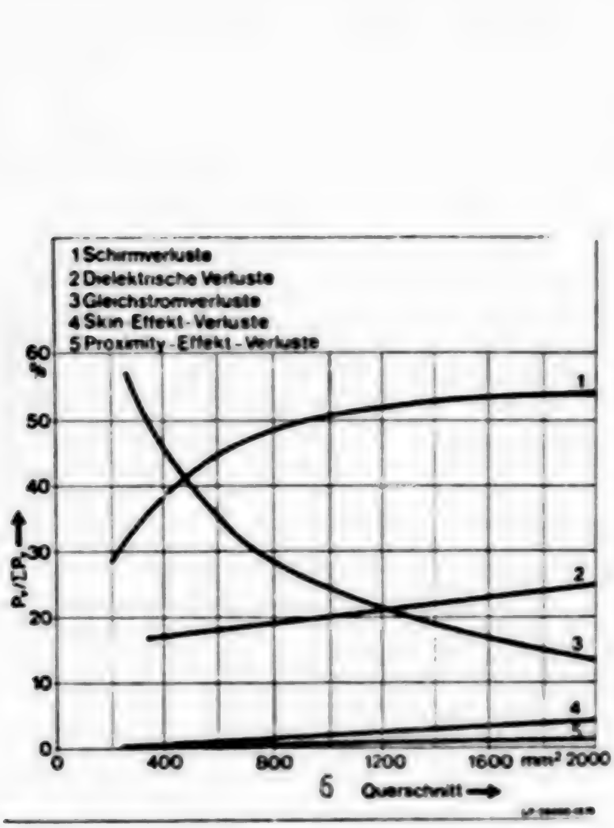

Figure 1. Loss components in a 380 kV oil cable, in dependence on conductor cross-section

1 shielding losses
2 dielectric losses
3 DC losses
4 skin effect losses
5 proximity effect losses
6 cross-section

When the cable is laid above-ground, on supports, heat is dissipated by convection and radiation through the ambient air as a cooling medium. Here there is no such problem as the ground drying out, so that the cable can be loaded more heavily in comparison to ground lines. The starting point for calculations is an ambient air temperature of 30° C.

If the cables are located in unventilated and covered channels, the heat that is generated can essentially be dissipated only through the channel walls. This creates a heat build-up, the temperature rises, and the load on the cable must be reduced. However, heat dissipation from the cable can be significantly improved by outside ventilation of the channel. The air speed here should not exceed 5 m/s, in order to avoid troublesome noises.

Reduce Cable Losses - Improve Heat Dissipation

In order to reduce cable losses and improve heat dissipation, suitable constructive measures and new laying techniques are used, as shown in Figure 2. The SF_6-gas insulated cable uses three characteristics for increasing its transmission power.

The large gap between the current-carrying conductor and the grounded sheath, which is required by the lower break down strength of the SF_6 gas, considerably reduces dielectric losses.

The SF_6 gas conducts heat very well, and consequently improves the internal heat transmission from the line to the cable sheath.

The large cable diameter implies a large cable sheath surface, whereby more heat can be dissipated to the ambient cooling medium.

SF_6 Has Proven Itself in Switching Systems

Besides the familiar cable types such as oil cables, internal gas pressure, external gas pressure, and PE cables, SF_6 tubular gas cables have recently gained in significance as high power cables [3]. After the SF_6 technology proved itself in switching systems, it seemed to lie near at hand, on the basis of this experience, to use SF_6 gas also for insulating high voltage cables [4 through 7]. First, leaning on bus bar elements of fully encapsulated, SF_6-insulated switching systems, rigid single-phase tubular cable segments with concentric inner conductors were developed. The conductor was here supported by solid insulators in a metallic, tubular sheath. The cavity between the conductor and the cable sheath is filled with pressurized SF_6 gas as insulating medium. The ratio of the sheath diameter D to the conductor diameter d is chosen so that the maximum allowed field strength $E_{r\,max}$ is used at the conductor, while a maximum operating voltage U is reached between the conductor and the grounded sheath.

According to Figure 3, the following formula holds for the potential V of a line charge q_L:

$$V = \frac{q_L}{2\pi \varepsilon_0 \varepsilon_r} \cdot \ln \frac{1}{r} \qquad (2)$$

The potential difference between the conductor surface and the cable sheath is the voltage U:

$$U = \frac{q_L}{2\pi \varepsilon_0 \varepsilon_r} \cdot \ln \frac{r_2}{r_1} \qquad (3)$$

The electric field strength E_r in the radial direction is calculated from:

Figure 2. Possibilities for increasing the transmittable power in cables

1 increasing the cable power
2 smaller losses
3 current-dependent
4 higher voltage
5 increasing the cross-section
6 normally conducting low temperature cables
7 conductor resistance
8 specific resistance
9 DC cable
10 superconducting cable
11 dielectric
12 plastic insulated cable
13 better heat dissipation
14 heat resistance of the insulation
15 gas-insulated cable
16 heat dissipation to the environment
17 larger cable diameter
18 stabilized ditch filling
19 artificial cooling

(4)

If the line charge q_L is eliminated from equations 3 and 4, one obtains the electric filed strength E_r from the following equation

$$\bar{E}_r = -\text{grad } V = \frac{q_L}{2\pi \varepsilon_0 \varepsilon_r} \cdot \frac{1}{r} \tag{5}$$

The maximum field strength prevails at the conductor surface, since the equipotential line with smallest curvature is present there, i.e.

$$E_r = \frac{U}{r \cdot \ln \frac{r_2}{r_1}} \tag{6}$$

The most favorable cable dimensions are obtained from the maximum controllable voltage U, i.e. under conditions where the function $U = f(r_1)$ has the maximum.

$$E_{r\,max} = \frac{U}{r_1 \ln \frac{r_2}{r_1}} \tag{7}$$

According to equation 7, the dimensions of the cable will therefore be scaled in such a way that the ratio of the sheath diameter D to the conductor diameter d will be about 2.7. The capacitance C' of the cable will then be

$$C' = \frac{2\pi \varepsilon_0 \varepsilon_r}{\ln \frac{D}{d}} \tag{8}$$

and the inductance L' will be:

$$L' = \frac{\mu_0 \mu_r \cdot \ln \frac{D}{d}}{2\pi} \tag{9}$$

The characteristic wave impedance Z of the cable is therefore as follows:

$$Z = \sqrt{\frac{L'}{C'}} = \frac{1}{2\pi} \cdot \ln \frac{D}{d} \sqrt{\frac{\mu_0 \mu_r}{\varepsilon_0 \varepsilon_r}} \tag{10}$$

With $\varepsilon_r = \mu_r = 1$, and $D/d = e$, there follows for an SF_6-insulated tubular gas cable:

$$Z \approx \frac{1}{2\pi} \cdot \sqrt{\frac{\mu_0}{\varepsilon_0}} = 60\ \Omega \tag{11}$$

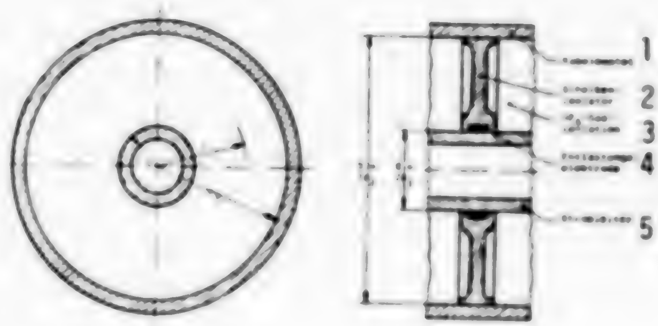

Figure 3. Design structure of the SF_6 tubular gas cable

1 cable sheath
2 disk insulator
3 SF_6 gas insulation
4 relief electrode
5 current conductor

In comparison to an oil paper cable ($\varepsilon_r = 3.6$), which is likewise designed as a single-phase coaxial cable for high voltages, the capacitance of the SF_6 tubular gas cable is smaller by the factor $1/\varepsilon_r = 0.28$. The characteristic wave impedance is larger than that of the oil cable by the factor

$$\sqrt{\varepsilon_r} = 1.9.$$

Consequently, the SF_6-insulating tubular gas cable, in comparison to the oil cable, has the following advantages:

Dielectric losses are smaller by the factor 0.28, according to equation (1), and thermal relief through an induced charging current is advantageous, especially at high transmission voltages.

Since the characteristic wave impedance of the SF_6 tubular gas cable is about twice as high as that of oil cable, the SF_6 tubular gas cable could even be operated with natural power, that is without reactive power (Figure 4).

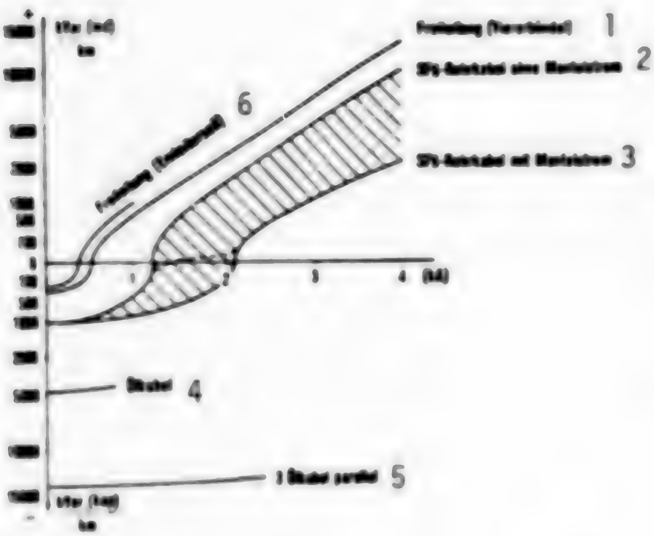

Figure 4. Reactive power of various transmission means for 220 kV

1 overhead line (four bundle)
2 SF_6 tubular cable without sheath current
3 SF_6 tubular cable with sheath current
4 oil cable
5 three oil cables in parallel
6 overhead line (single conductor strand)

The smaller charging currents permit longer transmission distances without using expensive compensation means (Figure 5).

SF_6 Cable - Between Oil Cable and Bare Line

Both as regards charging power and characteristic wave impedance, the SF_6 tubular gas cable occupies a place between the conventional oil cable and the bare line.

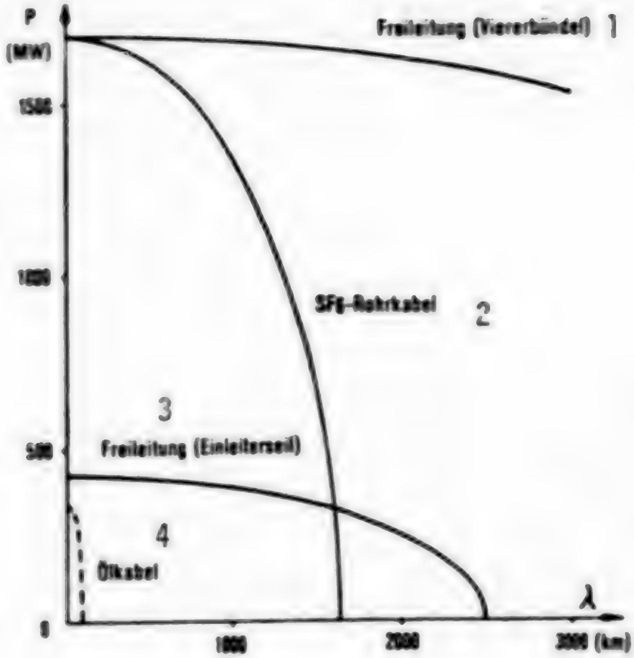

Figure 5. Transmission power for various transmission means at 220 kV, in dependence on transmission distance

1 overhead line (four bundle)
2 SF_6 tubular cable
3 overhead line (single conductor strand)
4 oil cable

Conventional oil cable	C' = 200 nF/km Z = 30 Ω
SF_6 tubular gas cable	C' = 55 nF/km Z = 60 Ω
Bare line	C' = 10 nF/km Z = 300 Ω

With oil paper cable, the permitted field strength at the conductor is 10 - 12 kV/mm. Because of the lower breakdown strength of the SF_6 gas, the field strength at the conductor surface of SF_6 tubular gas cables, at an SF_6 gas pressure of about 4 bar and at 20° C, is limited to about 3 kV/mm. - Nota bene, there is no relationship between the breakdown strength and the dielectric constant -. As regards the line charge q_L, the smaller allowed field strength for SF_6 tubular gas cables, as compared to conventional oil cables, requires four times as large a line diameter d. According to equation (7), the same also holds for the sheath diameter D, so that SF_6 tubular gas cables are about four times as thick as oil paper cables. However, disadvantage of larger dimension with the SF_6 tubular gas cable, is counterbalanced by the advantages of lower operating capacitance, good heat conduction of the SF_6 gas, and better heat dissipation

through the larger cable sheath surface. Conventional high power cables without supplementary cooling are limited in their transmission powers to conduct the current up to about 800 A, because of thermal reasons, so that they can sensibly be designed only up to a conductor cross-section of 1000 mm^2 Cu, even though cross-sections of 2000 mm^2 Cu would be easily possible in terms of production. By contrast, SF_6 tubular gas cables can transmit nominal current up to about 5000 A.

Flexible SF_6-Insulated High Voltage Tubular Gas Cables

The previous idea of a rigid SF_6 tubular gas cable, composed of many short bus bar segments, is explained from a design philosophy of switching systems engineers, who began to use the SF_6 technology. Only much later on, did cable engineers recognize the advantages of SF_6 gas insulation, with all the resulting consequences for the production, transport, and laying technology. They then developed a flexible SF_6 tubular gas cable. The precondition for this was the development of a technique for corrugated sheaths, made of cable metal. The model was a high frequency antenna cable developed for the broadcasting station at Wertachtal, southwest of Augsburg.

The flexible SF_6 tubular gas cable, consisting of cable metal, was developed under the leadership of Prof. Wanser. It is a single-phase encapsulated cable with coaxial construction [8 through 11]. The outer tube, which represents the encapsulation, consists of aluminum. It is seam-welded along its length and is provided with spiral corrugations. The central conductor is formed of aluminum wires, which are stranded about a corrugated copper tube as support. To smooth out the conductor, the wire bundle is enclosed by another corrugated copper tube, whose corrugations are shaped so as to be favorable for the field (Figure 6). The current-carrying conductor is supported in the radial direction, in a central position with respect to the encapsulation, by spacers, which are designed as disk-shaped solid insulators. The development of the disk insulators was especially problematical, since they must be designed separable in the radial direction. Since the cable must be produced in a continuous production process, the disks must be placed on the conductor in two halves. The solid insulators consist of pressed Polysulfon, and their spacing in the axial direction is about 50 cm. The material chosen meets the given requirements as regards temperature stability, mechanical and dielectric strength, as well as application in an SF_6 atmosphere. The cavity between the conductor and the encapsulation of the single-phase SF_6 tubular gas coaxial cable is filled with SF_6 gas at a pressure between 3.6 and 6.0 bar and at a temperature of 20° C.

SF_6 Tubular Gas Cables Are Produced Continuously

The new flexible SF_6 tubular gas cables are produced in a continuous production process on the "Growema" machine, which was constructed of cable metal especially for this purpose. At this time, the cables are produced

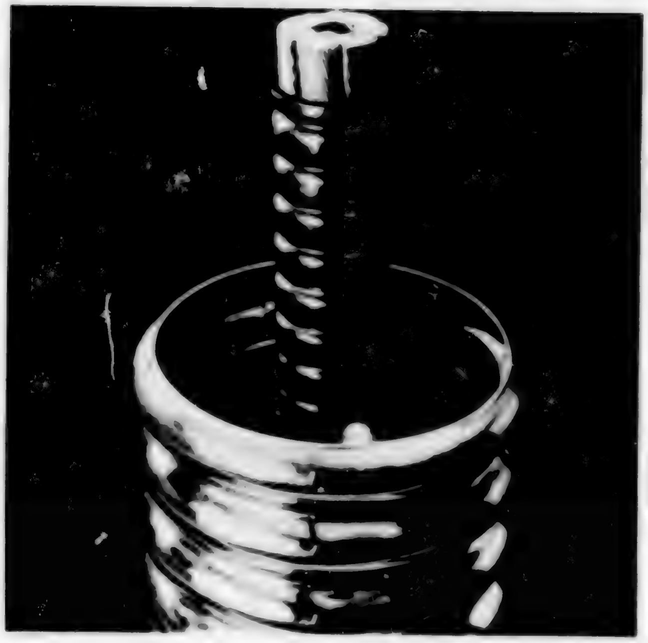

Figure 6. Design structure of the flexible SF_6 tubular gas cable

up to an external diameter of about 300 mm (Figure 7, 8). 220 kV cables, with an external diameter up to 300 mm, can be wound up to a length of 100 m on a drum with a flange diameter of 4.5 m. They can be brought to their installation site by rail or by road transport. 110 kV and 150 kV tubular gas cables, with an outside diameter of 250 mm, can even be wound on drums to a length of 180 m (Figure 9).

The traditional technology of rigid SF_6-insulated tubular gas cables makes it possible to deliver only 12 meter lengths to the construction site. By comparison, the flexible SF_6 tubular gas cable has the following advantages [10]:

Delivery of the cables to the installation site by rail or road transport on a cable drum.

Pulling off the cable with a traditional technique, using winches and cable grips over mounting rollers; this results in short mounting times at the installation site (Figure 10).

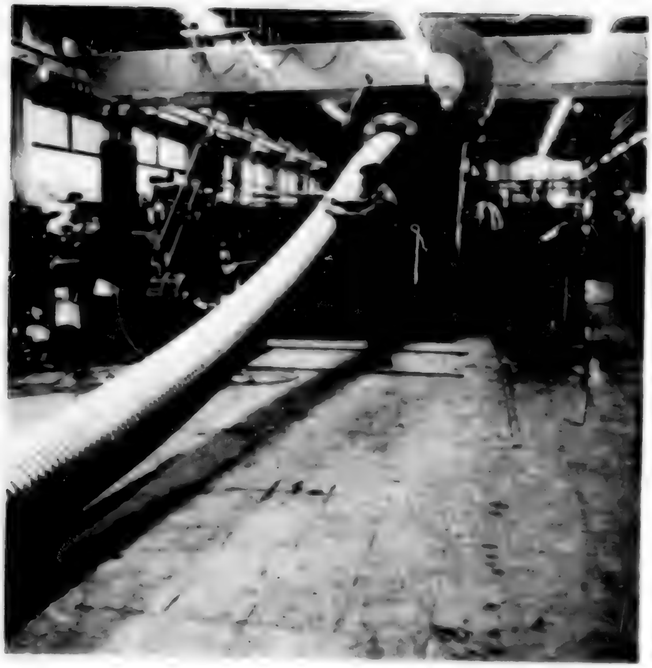

Figure 7. Continuous production process to manufacture the flexible SF_6 tubular gas cable. The conductor, with the disk insulators set up on it, slides into the cable sheath, which is subsequently rounded, welded, and corrugated.

Figure 8. The flexible corrugated sheath tubular gas cable is being ejected from the continuous production line

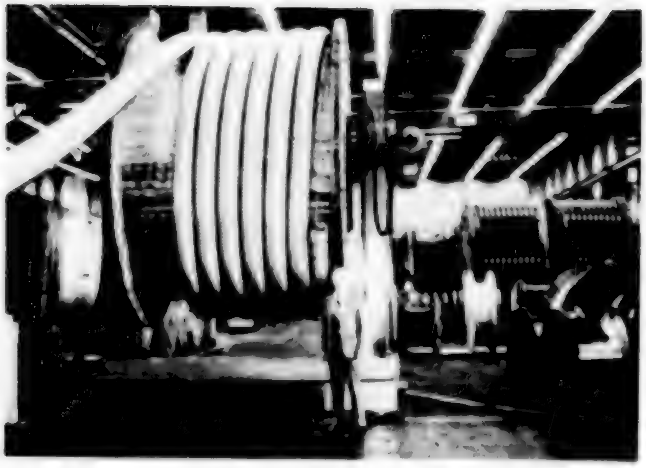

Figure 9. Winding up the flexible SF_6 tubular gas cable on a drum, after it leaves the continuous production line.

Connection of cable segments in lengths of 100 m and more; compared with rigid SF_6 tubular gas cable technology, the number of pressure tight components that must be produced on site is thereby reduced by about one power of ten.

The expansion pieces to compensate thermal stresses, which are necessary with rigid tube connections, can be omitted.

Bends and angle pieces, when the layout turns at an angle, can be avoided if the radius does not fall below the minimum bending radius of the flexible SF_6 tubular gas cable.

Table 1 shows the design data for flexible SF_6 tubular gas cables, which are at this time fabricated of cable metal for nominal voltages 110 kV, 150 kV, and 220 kV. Table 2 gives values of the transmission power, when the cables are laid insulated under the following presuppositions:

The insulating joints are built in section by section, and the cable sheaths are separately linked and grounded after each joint.

Or the cable sheaths are cross-jointed at uniform intervals (whose length should yield a value of the cable line divisible by three).

When laying cable in the ground, the proven combination of Polyment with extruded polyethylene is used as insulation and corrosion protection for the cable sheath. When laying overhead cables, a special coating imparts

adequate protection.

The flexible SF_6 tubular gas cables are transported with a slight gas overpressure (0.5 bar nitrogen), as ready-made lengths. They are equipped with fittings, are tested in the plant, are sealed gas-tight, and are delivered to the construction site. In this way, it is possible to eliminate the risk of impairing the insulation during the mounting process by moisture or dust penetrating into the insulation space.

Table 1. Design data for flexible SF_6 tubular gas cables according to cable metal

Nominal voltage (kV)	110	150	220
Outer diameter of the sheath (mm)	250	250	300
Conductor cross-section (mm^2 Al)	3000	3000	3600
SF_6 nominal pressure (bar at 20° C)	3.6	5.5	6.0
Test pressure (bar)	4.5	7.0	7.5
Bursting pressure (bar overpressure)	>22	>22	>30
Weight of the cable (kg/100 m)	2500	2500	3800
Diameter of the drum (m)	4.5	4.5	4.5
Length that can be transported on the drum (m)	180	180	100
Minimum bending radius (m)	2.5	2.5	3.0

Table 2. Data of current loadability for insulated laying of the cable

Nominal voltage (kV)	110	150	220
Standing surge voltage (kV)	550	750	950
Standing alternating voltage, 1 min (kV)	230	325	395
Rated current (A) when laid in air	2600	2600	3150
Rated current (A) when laid in ground (stabilized ditch fill)	1800	1800	1900
Nominal short term current, 1 s (kA)	40	40	40
Nominal surge current (kA)	100	100	100
Operating capacitance (μF/km)	0.055	0.055	0.060
Charge current (A/km)	1.0	1.5	2.4
Operating inductance (mH/km)	$\sim$ 0.65	$\sim$ 0.65	< 0.70
Conductor temperature at rated current (°C)	95	95	95
Current heat loss at rated current (kW/km)			
Laying in air	348	348	497
Laying in the ground (stabilized ditch fill)	167	167	182
Dielectric losses at rated voltage (kW/km)	<1	<1	<1

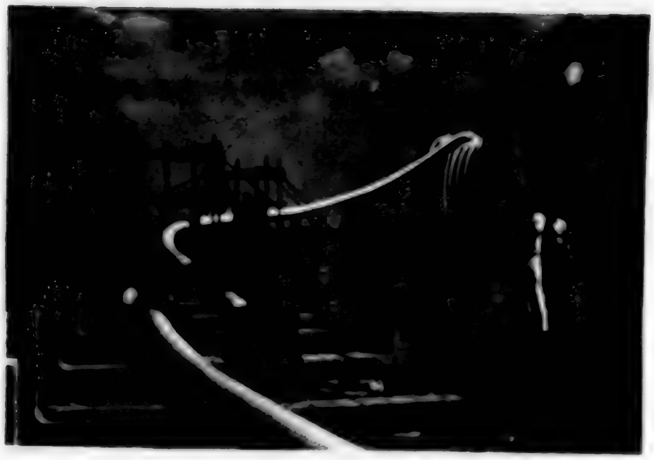

Figure 10. Pulling process of the flexible corrugated sheath tubular gas cable with winch and cable grip.

The Cable Segments Can Be Easily Linked

Ready-made lengths of cable are delivered to the construction site. The SF_6 tubular conductor system is accordingly subdivided into several sections by pressure-tight and gas-tight locking joints. The gas pressure in each section is monitored separately. Since the dielectric strength of an SF_6-insulated arrangement depends primarily on the density of the insulating gas, and since the pressure varies with temperature, temperature-compensated gas density monitors are used to monitor the pressure.

Once the cables are laid, the individual gas chambers, starting from the shaft works, are evacuated and are filled with SF_6 gas. The shaft works are always arranged at a distance of two gas chamber lengths along the cable line. Since all the gas chambers are equipped with vacuum couplings, which can be activated without loss of gas and pressure, this work can be performed very easily. Untight fittings or locking joint connections are detected with a leakage finder and are removed.

The flexible SF_6 tubular gas cables can be quite simply connected to transformers and to encapsulated, SF_6-insulated switching systems. This is done through SF_6 lead-ins, which have already been tested for many years and which have by now been standardized in Germany. SF_6-cable end connections are available for overhead transmission lines. These are arranged in such a manner that the required air gaps are maintained at the blank connecting bolts.

Testing These Flexible SF_6 Tubular Gas Cables

When testing cables, a distinction must be made between type and routine

tests in the manufacturing plant and on-site tests after assembly into a complete system.

Flexible SF_6 tubular gas cables are now available up to an operating voltage of 220 kV, and such cables have been tested in extensive test series. Long term experiments were performed to determine the gas tightness of the corrugated tubular sheath and of the fittings, with 1.5 times the maximum operating pressure, at various temperatures. A large number of bending tests was also performed. The electrical type test of the cable comprised a demonstration of insulation resistance corresponding to VDE 0670 Part 8/2.78, which is valid for metal-sheathed high voltage systems, with lightning surge voltages 1.2/50 µs, switching surge voltages and test alternating voltages 50 Hz, as well as heating measurements with cyclic current loads for systems laid in the ground and in overhead lines. Furthermore, the deformation behavior of the solid insulators was studied in long-term experiments at elevated operating voltage.

The routine factory tests, which are performed as a piece test, provides for the following measurements:

Determination of the electrical resistance of the conductor.

Hydraulic pressure tests to determine the gas tightness of the cable sheath.

Tests with a 50 Hz alternating test voltage, one minute.

Lightning surge voltage test, 1.2/50 µs.

Determination of partial discharge interrupt voltage.

During and after assembly of the cable, on-site checks and a final test are performed. To evaluate the joint connections, the ohmic resistance to the current path is checked at the connection points, and the gas leakage rate is determined. At the conclusion of the work, the entire system is subjected to an on-site voltage test. The capacitance of the tubular gas cables is about 55 nF/km. With an alternating voltage test of 50 Hz, this would require a mobile test transformer unit of considerable size. Consequently, the German Working Group in the IEC-SC 17 C "High Voltage Tests of SF_6 Systems" [12] has proposed a test method with oscillating switching surge voltage. Because of the simple test equipment, this test method is used for on-site voltage tests wherever an alternating voltage test of the line frequency cannot be implemented. This method also allows the acquisition of the capacitive voltage distribution at the solid insulators of the SF_6 tubular gas cable. This voltage distribution is decisive for operational purposes. By contrast, the direct voltage test, which is used for conventional oil paper cables, can only determine the ohmic potential distribution. The test with steep lightning surge voltages should be omitted at the installation site. Because of

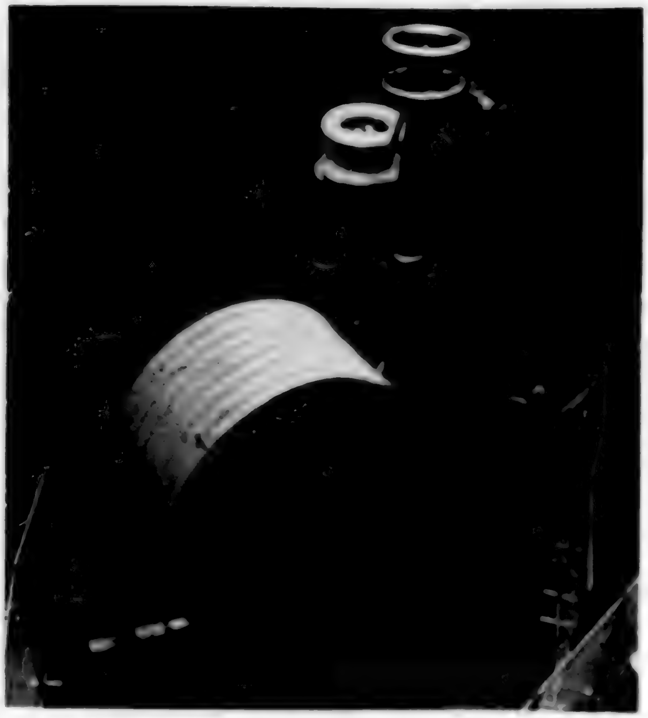

Figure 11. Voltage test of a ready-made cable length in the high voltage test area.

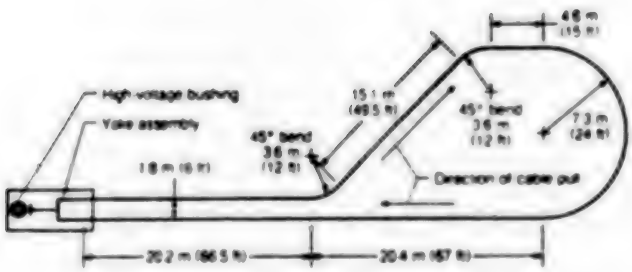

Figure 12. Laying a 345 kV SF_6 tubular gas cable in the cable test area of the EPRI in Waltz Mill in Pennsylvania/U.S.A., to perform a six months long-term test with cyclic current loads.

reflections in an extended cable system, it cannot be guaranteed that the maximum stress was the same at all points in the system.

Cable Damage Immediately Triggers An Alarm

For monitoring purposes, the gas chambers of the SF_6 tubular gas cables are equipped with contact manometers in the shaft work. In similar fashion as with encapsulated SF_6 insulated switching systems, these units trigger an alarm when the pressure of the SF_6 gas drops. If the gas pressure drops still further, they switch off the cable system.

When cables are laid in the ground, the problem of fault location is especially significant. With the SF_6 tubular gas cables, one can essentially have recourse to methods which are known from nitrogen-filled tubular gas cables. Partial discharges in the cable can be sensed by demonstrating the decomposition products in the SF_6 gas. This is done by withdrawing gas specimens and subjecting them to a gas analysis. The site of the trouble can be determined by ultrasonic detectors. The search for cable sheath defects is pursued with SF_6-sensitive halogen measurement probes.

In repairing the cable, the faulty cable segment is cut out and is replaced by a new one. First, the SF_6 gas is pumped out of the affected gas chamber, through a vacuum coupling from the shaft works. Prefabricated parts are used to make the connection at the interfaces. After the repair work has been completed, the repaired gas chamber is evacuated and is refilled with SF_6 gas. Before the cable is again put into operation, a voltage test is performed. It takes about a week to make a repair.

What Are The Limits of The Flexible SF_6 Tubular Gas Cable?

The further development of the flexible SF_6 tubular gas cable aims at a transition to higher transmission voltages. For this reason, a 100 m long 345 kV cable has been fabricated of cable metal. It has an outer diameter of 300 mm. It was laid in the American cable test area Waltz Mill in Pennsylvania. Transport in the U.S.A. and the on-site pulling of the cable into the ditch in the form of a loop was effected without problems. At this time, the cable is being tested by the EPRI (Electric Power Research Institute), after checking the rated standing voltages in a six month fatigue test with cyclic current loads. Experiments performed up to now have been successful [13]. On the basis of results of this study, flexible SF_6 tubular gas cables should be developed with an outer diameter of 400 mm and for a rated voltage of 380 kV.

References

[1] E. Abilgaard: Future prospects for the transmission of electrical

energy with overhead lines and cables. Energie und Technik (Energy and Technology) Number 4, 1973, pp 3-12.

[2] G. Wanser: Lecture manuscript energy cables (unpublished), Hannover Technical University.

[3] D. Kind: Gas insulated energy transmission systems. Berhhard Price Memorial Lecture. Sept. 1974. South African Institute of Electrical Engineers.

[4] A. Eidinger: Future possibilites for the transmission of very high powers. Electrotechnik und Maschinenbau (Electrical Engineering and Machine Construction) 90, 1973, Vol 6, pp 269-275.

[5] A. Eidinger, C.D. Flössel: Energy transmission by means of tubular gas cables, a comparison with conventional transmission means. International Symposium for High Voltage Engineering from 9 to 14 March 1972 at Munich Technical College.

[6] A. Eidinger, W. Klement: Underground power transmission using compressed gas insulated cables. CIGRE Paper 21-11, 1974.

[7] G. Bähr, W. Lehmann: SF_6-insulated metalclad 420 kV tubular bus with transfer facility connected to an underground hydroelectric power station. CIGRE Paper 23-02, 1974.

[8] E. Scheffler: Welded corrugated sheaths as construction elements for novel high power cables. International Symposium for High Voltage Engineering from 9 to 14 March 1972 at Munich Technical College.

[9] P. Brückner: SF_6-insulated conductor systems for high power transmission. ETZ - A 92, 1971, pp 733-737.

[10] E. Abilgaard: The laying of SF_6-insulated high voltage tubular cables. Energie und Technik (Energy and Technology) Vol 4, 1972, pp 127-133.

[11] G. Wanser: The corrugated sheath as a construction element for gas-insulated cables. Contribution to a discussion at Cigré, 1966, unpublished.

[12] W. Boeck, D. Kind, K.H. Schneider: High voltage tests of SF_6 system on-site. ETZ - A 94, 1973, pp 406-412.

[13] R. W. Samm: Flexible gas cable. Contribution to a discussion at CIGRE, Study Committee No. 21, Paris 1978.

[14] G. Wanser: New construction forms of future high power cables. Lecture at the VDEW (Union of German Electrical Works) - Cable Commitee 1967, unpublished.

[15] G. Wanser et al.: Possibilities for future subterranean energy transmission. Paper on the Cable Seminar at Hannover 1972, unpublished.

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DESALINATION OF WATER WITH SOLAR POWER

Rome FONTI DI ENERGIA ALTERNATIVE in Italian No 2, Mar/Apr 79 pp 22-27

[Article by B. Agricola, Nuclear Plant Laboratory, College of Engineering, Rome, and V. Cena, Analysis and Development of Energy Systems, Rome: "Solar Desalination: Current Status and Developmental Potential"]

[Text] Summary.--Among the numerous applications of solar energy, solar desalination stands out not only as a reality of current interest but also because of its potential for further development.

The desalination of seawater is a process of considerable interest, especially to those developing countries with an abundance of the required principal ingredients: sunshine and a lack of fresh water.

The simplicity of construction of certain types of plants and their long service life are factors that ensure their intensive development within a relatively brief time span.

The purpose of this article is to provide a critical analysis of the various solutions that have been proposed to date, to evaluate their technical characteristics, and to assess their economic viability as a function of scale factor and of predictable evolution of certain parameters of interest.

Finally it discusses the developmental lines of current research and the objectives that are attainable in the short and medium terms from the standpoint of their industrial realization.

1. Introduction

Solar energy has been used for a very long time now in various medicinal processes (for example, for the extraction of perfumes and medicinals from precious herbs, etc). The earliest known documented reference to it is that of an Italian, Nicolo Ghezzi, who in 1742 proposed a method for distilling seawater through the use of solar energy. The first solar distillation still of significant dimensions was of the "greenhouse" type that

dates back to 1672. Designed by Charles Wilson, it was erected in Chile at Las Salinas. A detailed description of the still, written by Harding in 1883, estimates the area of its glass-covered collecting surface to have been over 4,500 square meters, and its potable water productive capacity over 1,500 [as published] liters per day. This still operated over a period of about 40 years (although at diminishing capacity), that is, until Las Salinas was reached by an aqueduct.

Subsequently (1926), the French government provided a substantial boost to studies in this field when it published a competition for the design of a portable solar still to be used by colonial troops in Africa. Many and very interesting were the designs submitted, some of which even included solar concentrators.

Many further initiatives followed. In 1952, the Office of Saline Water was created in the United States, which stimulated the design and construction of solar stills. This initiative began to bear fruits as early as 1953.

Other countries besides the United States also undertook initiatives in this sector.

In Australia, by 1966, stills with covered collecting surfaces of over 5,000 square meters were being built.

In Chile, solar plants were designed to produce electricity and desalinated water (up to 28,000 liters per day and 250 kilowatts).

Interesting initiatives were undertaken concurrently in Russia, Italy, France, India, Iran, Spain, Egypt, Japan and Tunisia.

In Greece, especially, construction was started in 1964 on several solar desalination plants. Between 1964 and 1969, plants were built totaling 18,000 square meters or more of collecting surfaces.

Various technical solutions have resulted.

The purpose of this article is to present from a critical viewpoint the functional schemes of the different plant designs and to indicate their developmental possibilities. This is followed by a discussion of the results of a study made by the authors on obtainable economies in solar desalination plants as a function of type of plant, scale factor, and evolution of certain parameters of interest. Finally, the developmental lines of current research are considered, as well as achievable objectives over the short and medium terms from the standpoint of production on an industrial scale.

2. Solar Desalination Plants

Solar desalination can be achieved by two different approaches: processes based on a low-level technology (basin desalters) requiring commonly available materials and unskilled labor, and processes based on high-level technology that combine flat-plate solar collectors or solar concentrators with conventional distillation plants (multistage flash, multiple-effect, vapor compression, humidification). Following is a brief discussion of the basic operating principles of the various processes.

2.1 Low-Level Technology Plants (Basin Desalters)

This type of plant consists of a number of rectangular cement basins(blackened with butyl rubber or asphalt) covered with sloping glass or plastic plates under which troughs running along the sides of the basin collect the moisture that condenses on the underside of the plates.

The operating efficiency of these basins is highly sensitive to a number of factors, such as: variations in sunlight intensity, wind velocity, a ambient temperature, rainfall, basin depth, vapor-tightness, distillation losses, deterioration of the thermal insulation underneath the basin, deterioration of the optical properties of the covering material, system operational factors (treatment and/or preheating of incoming water, variations in input/output ratio, frequency of maintenance).

The average cost of desalinated water produced in this manner (at 1976 prices), taking into account also the daily yield of fresh water per square meter, oscillates between 3,000 and 3,500 lire per cubic meter, decreasing only very slightly with increasing size of the plant because of its modular construction, which does not permit an appreciable economy of scale. The main component of this cost (more than 75 percent) is the plant amortization cost, even though depreciated over a period of more than 20 years.

The conditions under which basin desalters appear to be a valid choice are concurrently the following: adequate sunshine, an isolated community (island, desert), a demand of less than 200 cubic meters of fresh water daily, and limited availability of specialized labor capable of operating a sophisticated plant. The disadvantages, on the other hand, are: the aforementioned lack of economy of scale, the need to cover rather vast areas, and, above all, the initial investment (of the order of 30,000 lire per square meter).

2.2 High-Level Technology Desalination Processes

These systems use two separate subsystems: one designed to collect the solar energy, the other to transform it into latent heat of evaporation.

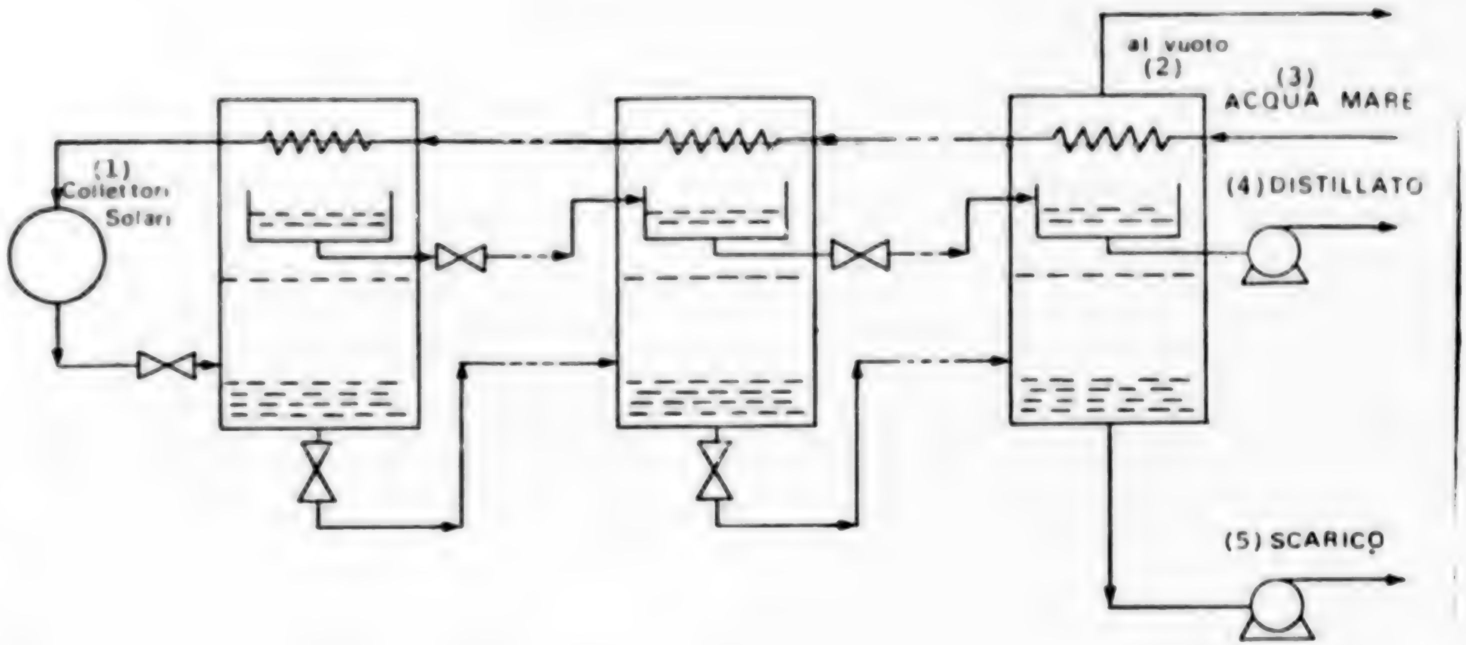

Fig 1 - Multistage flash distillation.

Key:

1. Solar collectors
2. Vent
3. Seawater
4. Fresh water
5. Brine

The collectors, whether of the flat-plate or concentrator type, are the same as those used in other applications. The systems may be designed around either of two operative concepts: in the one, the seawater is heated directly inside the collectors; in the other, an intermediate liquid (e.g., glycol) is made to circulate through the collectors, then through a heat exchanger where it transfers the heat it has received to the seawater. Since operating temperatures are of the order of 90 degrees C, the corrosion problem imposes the use of cupronickel or an aluminum alloy for the system components in contact with the heated seawater.

In the multistage flash distillation process (Figure 1), a flow of seawater is flashed into a number of successive stages operating at progressively lower pressures. The vapor produced in each of these stages is used to preheat the incoming seawater. The total temperature drop between the heated incoming seawater (solar collectors) and the cold source (sea) is thus equally distributed among the various stages, and the system approaches an ideal countercurrent flow with total recovery of heat.

This process reduces the energy input requirement to values between 30 and 120 kilocalories per liter as compared with the 600 kcal/l requirement of a simple distillation system.

The maximum number of stages is limited by the thermodynamic losses (ebulliometric rise and nonequilibrium), pressure losses in the system owing to friction, and the necessary compromise between efficiency of exchange and cost of exchange surface.

A study by us indicates that in the range between 50 and 500 cubic meters per hour of fresh water, the cost of the water decreases from 3,500 lire to 2,000 lire per cubic meter (see Figure 5). Optimal collector temperatures vary between 70 and 90 degrees C. All factors considered, solar multistage flash distillation plants are competitive with respect to conventional fuel-heated desalters, even though only by a small margin (around 5 percent).

In the multiple-effect evaporation process (Figure 2), the vapor produced in one effect condenses and evaporates additional water in the next effect and so on, at progressively lower pressures in the succeeding effects. For yields close to 50 cubic meters per hour of fresh water, this process is, although by a small margin, the most economical (around 3,000 lire per cubic meter).

In vapor compression plants (Figure 3), the vapor is compressed mechanically between one stage and another to raise its pressure and hence its saturation temperature.

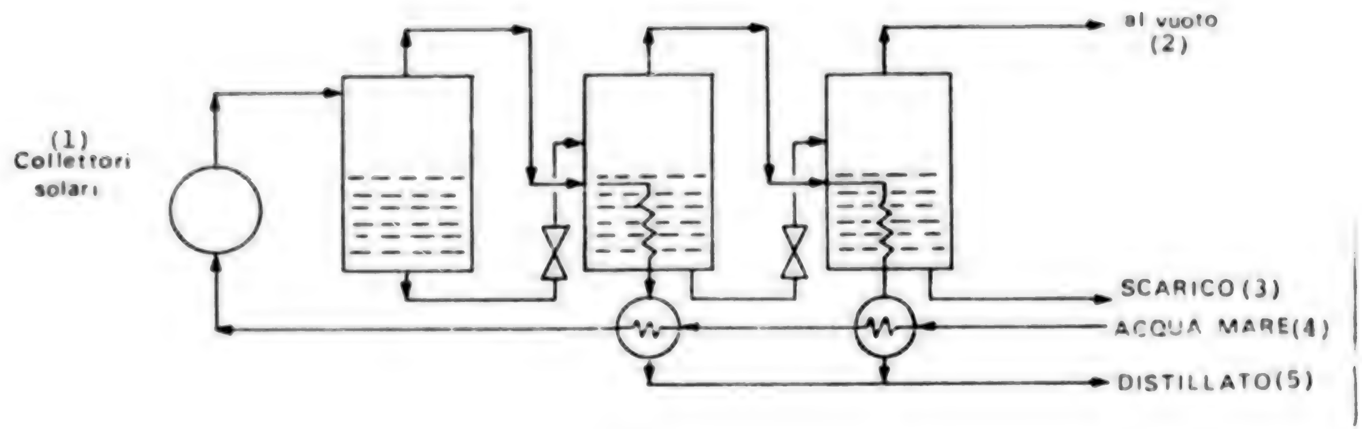

Fig 2 - Multiple-effect evaporation.

Key:

1. Solar collectors
2. Vent
3. Brine
4. Seawater
5. Fresh water

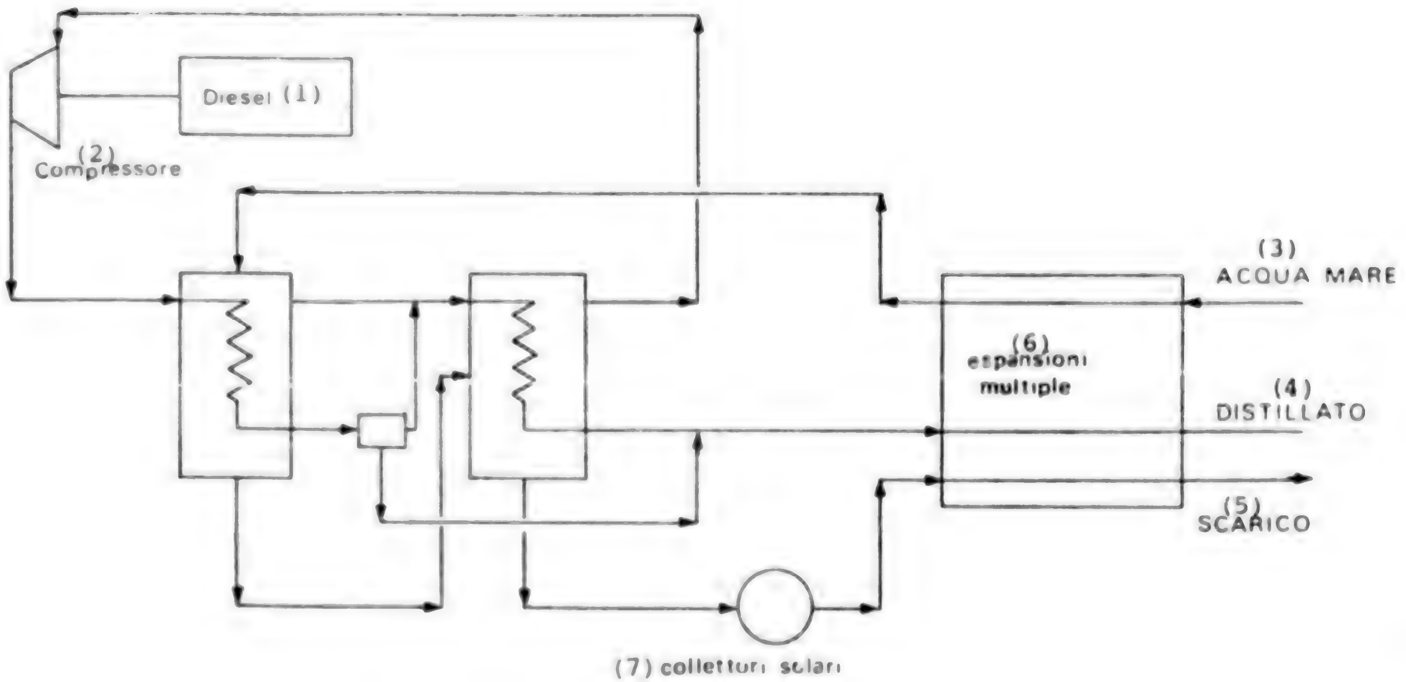

Fig 3 - Vapor compression.

Key:

1. Diesel engine
2. Compressor
3. Seawater
4. Fresh water
5. Brine
6. Multistage flash stages
7. Solar collectors

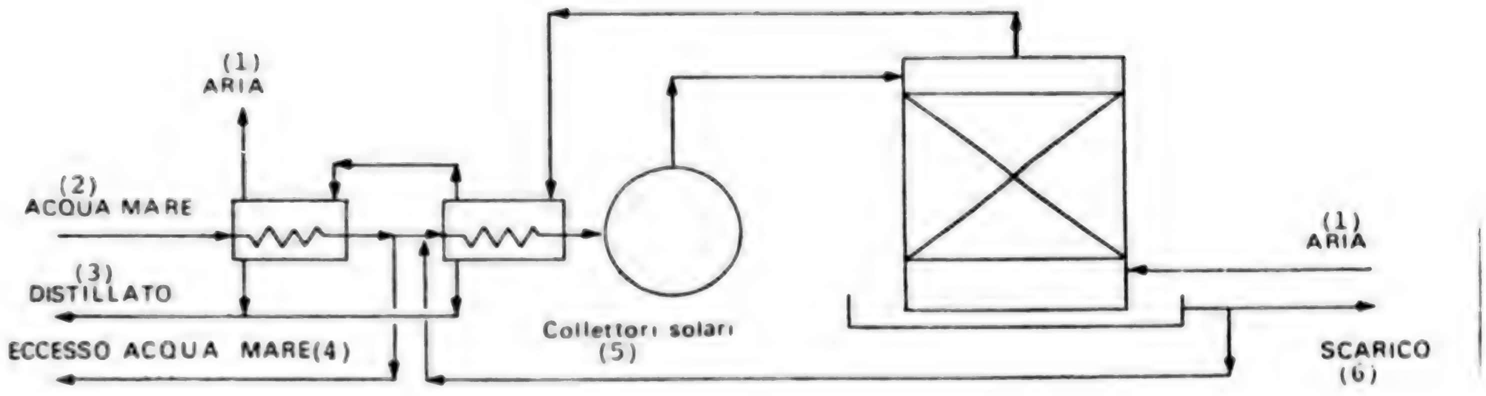

Fig 4 - Humidification-dehumidification

Key:

1. Air
2. Seawater
3. Fresh water
4. Excess seawater
5. Solar collectors
6. Brine

The vapor is then condensed, releasing heat to the stage from which it was taken. Our evaluation indicates that this type of process is not suited to the use of solar collectors. In fact, by using a diesel engine to drive the compressor, the recoverable heat from the engine's radiator is sufficient to provide all the thermal needs of the system.

In humidification-dehumidification plants (Figure 4), the incoming seawater is preheated in heat exchangers, then in the solar collectors. The heated water is then sprayed from above in a cooling tower where it heats and saturates the ambient air with moisture. The moist air then condenses and deposits water in heat exchangers.

This type of process, notwithstanding its use of conventional components and its low investment cost, requires an extremely large collector surface per unit volume of fresh water produced. Its overall efficiency is low as a result of enthalpy losses connected with the discharge of heated air.

In plants designed solely for the production of fresh water, costs exceed 10,000 lire per cubic meter. On the other hand, the economic aspect can change drastically if the plant is used also for the production of cooling and humidified air (for air conditioning and greenhouse farming). Some installations of this type are currently operating on a pilot scale.

3. Current Status and Future Trends

Figure 5 plots the costs of producing desalted water by combining solar energy with technologies currently in use. These curves show that in the range between 50 and 500 cubic meters per hour, fresh water can be produced at a cost between 2,000 and 3,500 lire per cubic meter, that is, at competitive prices with respect to desalination using fossil fuels.

Owing to the solar collectors, the total investment for a solar plant runs 30-50 percent higher than for a conventional plant. This additional cost is amortized in less than 10 years of operation, assuming the price of fossil fuels remains substantially constant ($15 a barrel). It is to be noted also that these costs are based on solar operation during the day and conventional operation at night, requiring no heat storage.

Below 50 cubic meters per hour, solar basins are the most economical and the most suited to the needs of relatively small communities (5,000-6,000 persons).

The medium- and long-term outlooks for solar desalination must be assessed on the basis of the predictable fossil fuel cost trend as well as on the course of technological improvements in solar collectors and in conventional desalters.

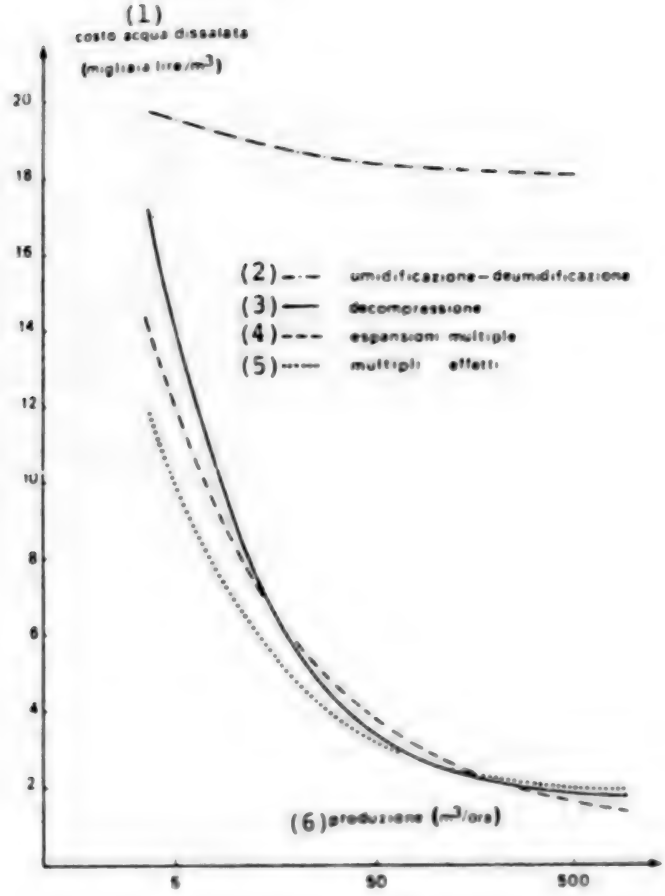

Fig 5 - Cost of desalted water using solar energy.

Key:

1. Cost of desalted water (thousand lire per cubic meter)
2. Humidification-dehumidification
3. Vapor compression
4. Multistage flash
5. Multiple-effect evaporation
6. Production (cubic meters per hour)

As regards oil prices, many projections anticipate a doubling of demand every 10 years and a quadrupling of prices for each tenfold increase in demand. This works out to a secular increment of the order of 1/24 per year on average, or a factor of 1.5 over the next 10 years.

As regards solar collectors, sensible development through standardization of production could achieve a reduction, for equal efficiency, from 100,000 lire per square meter to 60,000-70,000 lire per square meter.

A detailed analysis, technical as well as economic, shows that for plants with a capacity of 500 cubic meters per hour the cost of the water produced diminishes by 3 percent for a reduction of 10 percent in the cost of the collectors. Thus, in 10 years, the cost of desalting water by means of solar energy could be expected to diminish by approximately 10 percent, whereas that of desalting by conventional means will, owing to the oil price increase, probably be 10-12 percent higher than at present.

All things considered, the competitive margin of solar desalination, which today is of the order of 5 percent, will be 20-25 percent within 10 years.

To these economic considerations there must, of course, be added others that are not easily quantified: Conservation of resources, the ecology, the strategic and logistical problems of fossil-fuel supply, and the costs of transporting and storing these fuels are all arguments that militate in favor of solar desalination.

4. Development Objectives and Priorities

The determinant objectives in the outlook for solar desalination seem to fall into three main categories corresponding to the main subsystems of a plant: collectors, heat storage, and desalters proper.

4.1 Collectors

As regards collectors, their efficiency must be increased, especially in 70-90 degree C range that controls the economy of the process. At higher temperatures (around 120 degrees C) the efficiency, while still important, is more a function of the compatibility and resistance of the materials in contact with the water to be desalted, and substantial improvements are therefore not foreseeable in efficiencies at these temperatures.

It is equally important to raise maximum operating temperatures, in that each degree of increase in the latter results in a 2 percent reduction in the system's energy demand, and hence in its collecting surface. Against this economy there is about a 5 percent increase in cost of other components.

Considering the relationships of detailed to overall costs, each degree of increase in maximum operating temperature results in a reduction of 0.4 percent in total investment cost.

Research and development to improve collector efficiency must be centered mainly on:

--thermal insulation materials and geometry (conduction losses are still a major cause of dispersion);

--opticothermal properties and finish technologies of collector surfaces;

--reliability, assurance of mean service life, and improvement of these factors.

4.2 Heat Storage

The use of fossil fuel at night can be avoided by using a heat storage tank, thus doubling the economic advantage of a solar desalination plant over a conventional one.

The impact of doubling the collector surface on the total cost of the plant is in fact small, whereas the corresponding reduction in operating cost for the same fresh water output is substantial.

The avenues of research that are still open relate essentially to:

--identification of new heat storage systems based on chemical reaction;

--feasibility studies on storage based on latent heat;

--general systems design studies.

4.3 Processes

Since the basic processes are analogous to the conventional ones, and the performance of individual components is well known, only overall plant performance studies are considered under this heading.

Such studies must seek principally to determine optimal plant operating and management conditions with a view to reducing investment as well as operating costs.

Of special interest are general systems design studies on possible new overall plant schemes involving new combinations of subsystems. For example, studies might be carried out on how to insert solar collectors between the stages of a multistage flash or multiple-effect evaporator, with a conventional boiler at a higher temperature placed at the end. Other studies

could be undertaken in the direction of coupling desalination plants with power plants, with plants for recovering minerals from seawater, and with air conditioning plants.

5. Realizable Economies

Reduction of the costs of desalted water depends on many factors, some involving the industrialization of solar technologies and their widespread use on a large scale, and others involving the results of basic and applied research.

Since the solar technologies used for desalination plants are common in many respects to those of other solar plants used for industrial and civil purposes, their cost reduction also involves politicoeconomic factors that lie outside the strictly solar desalination field. We limit ourselves, therefore, to the more typical aspects of the problem related to the design of components and plants having better performance characteristics and greater reliability.

Achievable results, through an adequate research and development effort, that can improve the competitive viability of solar desalinators are:

--improvements in the design of collectors and in the opticothermal properties of their covers and selective surfaces to obtain 75 percent efficiency at 80 degrees C under a radiation intensity of 800 watts per square meter and at an incremental investment cost of less than 35,000 lire per square meter. Attainment of this objective would enable a savings, with respect to present costs, of approximately 10 percent on the collector subassembly;

--improvements in the reliability of collectors to the point of guaranteeing a service life of 15 years versus the current 10 years. This would result in a substantial reduction (of more than 20 percent) in the cost of water produced;

-design of low-cost (0.2 lire per 1,000 joules) heat storage systems in the temperature range of 80 ± 15 degrees C. This would limit having to resort to other energy sources for continuous plant operation;

--design of a working model plant for dynamic studies on desalters that can be started up and stopped in intervals of approximately 1/2 hour.

Optimization of a plant based on its dynamic behavior could result in economies of up to 10 percent in cost of the end product.

It should be noted, however, that not all of these desired objectives are achievable within the short term, even with an intensive research effort. There are, as a matter of fact, technological "design-hardening" times that cannot be shortened beyond certain limits; such times are related to actual construction and operation of industrial-scale prototype plants.

It is to be hoped, therefore, that the design of such industrial plants can proceed without further delay.

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